FACTS AND DEDUCTIONS BEARING ON THE ACTION OF THE NERVOUS SYSTEM.

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TO the student of the physiology of the day, the nervous system is apt to appear as a collection of complex and independent structures. He hears so much about centres and about localization, so much about the function of this part and the function of that, that he is apt to acquire a confused notion of so many *separate* things upon which the will plays very much as a man plays upon the keys of a piano. When, too, he comes to study nervous pathology the impression is apt to be confirmed, and his knowledge of detail displaces or rather suppresses ideas of a general nature. It has been partly to place in a prominent light the erroneous nature of such impressions, and partly to present some new views on the action of the nervous system, that this paper has been written.

The nervous system develops, as we know, from a simple longitudinal involution of the epiblast, and the various parts of the tube thus formed differ at first in no essential points from each other. It is only by a gradual change, here a dilatation, there a constriction, that the various segments of the cerebro-spinal tract arise, and the further differentiation of its parts proceeds in the same gradual manner without leap or break. Evidently, then, when development has been completed, when the highest degree of complexity has been reached, the nervous system, though made up of a myriad members, is still a *unit*, is still *one* *whole.* Again, in the beginning, all of its parts are in undeniable relation with each other, and in the adult state these relationships must still be maintained, though here and there they are less intimate.

Facts of comparative anatomy lead us in a similar direction. We have, to begin with, the undifferentiated simple nervous axis of the amphioxus, which corresponds to the primitive neural tube of the embryo. Then, by a gradual transition, we have differentiation of the encephalic and spinal portions up to the condition in which we find them in the higher mammals. The inference again is obvious that the mechanism, though complex, is still *one* and *not multiple.*

How is it that the nervous system, at the same time complex in structure and manifold in function, preserves its primeval character of a simple unit? Let us inquire more closely into the development of its parts, the segregation of its centres.

It is extremely probable that in a simple nervous system, such as we find in the amphioxus or see represented in the early stages of the embryo, the various functions are performed equally and indifferently by all portions. Now, evidently, the first step towards specialization must have been the *concentring* or *focussing* of certain functions in certain areas. This concentring or focussing of functions was probably determined by such simple facts as the mechanical relations of the nervous system to the other structures, certain functions being performed more readily in certain positions than in others. Again, given a concentring of function sufficiently well-defined, it must, in the course of time, have been followed by a change of structure more or less marked. It would readily appear, therefore, that the complex and highly differentiated nervous apparatus of mammals has arisen by a constant and cumulative repetition of this process. In some portions *great* structural modification has resulted, in others *little* or *none that is demonstrable;* as witness the various centres which physiologists are unable to fix and describe anatomically, but of the existence of which they feel no less certain.

Again, it is very evident that while in certain localities centres are being developed and structure correspondingly modified, there must still remain vast areas or tracts of nerve tissue in which little or no change has taken place and the function of which is still of a *general* character. That such areas whose functions are general or relatively general, are still present in every nervous system can, I think, be shown to be extremely probable. Let us take up, for instance, the much-discussed question of cerebral localization. Physiologists, as we know, have fixed upon certain portions of the cortex to which they ascribe the property of originating the voluntary muscular movements, and upon certain other portions to which they ascribe the property of perceiving the various sensory impressions. Now, as is well known, these areas, though distinctly defined physiologically, are poorly defined anatomically. A portion of cortex distinctly irritable passes without breach of continuity and without obvious or marked change of structure into portions of cortex that do not respond to any stimulus whatever. Again, this apportionment of the cortex leaves out the bulk of the vast surface of the brain, to wit, the frontal lobe, the island of Reil, the occipital lobe, all of the mesial and the greater part of the basal surfaces.

What then is the meaning of these vast areas? Attempts have been made, and upon unsatisfactory grounds, to ascribe the intelligence to the frontal lobes, and still less clear notions prevail with regard to the occipitals. As we proceed, such views will, I think, be shown in their very nature to be untenable. Obviously these large areas *are portions of the cortex whose functions are still relatively general.* The so-called motor and sensory areas, on the other hand, are nothing more than *points where functions general to the brain are concentred, and this concentring takes place because these points happen by their anatomical positions to be gateways of ingress and egress to the general cortex.*

Let us approach the subject from another standpoint.

The life in a child at birth is almost purely spinal. We know, from the researches of Flechsig and of Parrot, that, as regards the development of nervous tissue, its brain is in an embryonal condition, and that "it is the motor zones, so-called, that are first developed, and are the first to place themselves in relation with the bulbo-spinal system, by the intermediation of the pyramidal fasciculi. . . . It is only at the end of a month that the substance of the occipital lobe begins to whiten, and only after four months, and close to the fifth, do the anterior regions begin to be developed, and this development will not be accomplished until towards the ninth month." [1]

Now, to ascribe to the pyramidal cells of the motor areas *purely motor* ideas, is to my mind absurd. We must remember that although the cortex of the motor area is the first to develop, that, hand in hand with this development, the child is evolving, not only in the direction of voluntary movement, but also sensorially, intellectually, and emotionally, *psychically in every respect.*

Before leaving the subject of central localization, another point which appears inexplicable on any other view than that here maintained in relation to the development and integration of centres, is the localization of the faculty of speech in the left third frontal convolution. The question at once arises, What is the function of the *right* third frontal convolution? Obviously it is one of those areas possessing a function of merely general value, and, if the observation of Gratiolet, that the left frontal convolutions are developed before the right, be correct, we have a ready explanation as to why concentrating of function should have gone on in the left gyrus far in advance of the right.

The ideas thus far developed naturally suggest that the nervous system, in its simplest states at least, is *vicarious* in its action. As it becomes more complex such action must become more limited, yet even in highly differentiated forms evidences of the occurrence of such action should not occasion surprise. We are all aware that some physiologists claim its occurrence for the cerebrum, and that they ascribe the temporary character of the paralysis following ablation of certain cortical areas, to the function being taken up by corresponding parts in the other hemisphere or by neighboring areas in the same.[1] Certain facts of pathology also suggest this view. Extensive lesions caused by tumors of gradual growth are, as is well known, frequently unattended by noticeable symptoms. The obvious explanation is, of course, a supplementary or vicarious action by other parts of the brain.

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[1] "Lectures on the Path. Anat. of the Nervous System—Diseases of the Spinal Cord," by Charcot. Translated by Cornelius G. Comegys, 1881, pp. 30, 31.

Again, in such states as represented in the embryo and in amphioxus, the nervous system is undeniably a simple whole, and every one must admit that there is a maintenance of equilibrium among the parts of this whole. Now, whatever disturbs the equilibrium of a part, disturbs the equilibrium of the whole. Therefore, in this primitive nervous apparatus, changes taking place in any one part would affect all other parts as well. Now, if this be true of so simple a nervous system, it must unavoidably be true of one more complex. Though complex it is still a unit, and it must react as a unit. Facts depending upon this law of the maintenance of the equilibrium, have for a long time been recognized by physiologists, and have been described by them as phenomena of " inhibition." They tell us that certain centres are " inhibited " by others. In part they are right, in part they are wrong, for the action must be mutual—must be from higher to lower and lower to higher centre as well. That the brain inhibits the spinal cord is readily demonstrable, and this fact is not be wondered at. We have, on the one hand, a mass relatively large and complex; on the other, a mass relatively small and simple. In consequence, the latter is, as it were, overbalanced ; and yet relatively small and simple as the cord is, it must have a counterbalancing action on, the brain, though this is, in the very nature of the arrangement, not demonstrable. However, brain and cord are but parts of one thing, and it is but a question of action and reaction between parts.

Thus far we have endeavored to show, from general considerations alone, that the nervous system acts as a whole. Let us now turn our attention to other fields of evidence.

Several years ago, together with Dr. A. J. Parker, the writer made some interesting observations on the artificial induction of certain convulsive seizures.[1] As these experiments are of special importance to the subject in hand, a short account of them is here inserted. They were performed by subjecting one or more "groups of muscles to a constant and precise effort, the attention being at the same time concentrated upon some train of thought. . . . After the lapse of a variable period of time, . . . *tremors* commenced" in the part subject to the experiment, which was most frequently the hand. "These tremors became rapidly magnified into rapid movements of great extent, sometimes to and fro, sometimes irregular. If the experiment was now continued, the muscles of the arms, shoulders, back, buttocks, and legs, became successively affected, and the subject was frequently thrown violently to the ground in a strong general convulsion. The muscular contractions frequently became tonic, so that opisthotonus, emprosthotonus, and the most bizarre contortions were produced in various degrees."

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[1] See Exner, Hermann's "Hdb. d. Phys.," vol. ii., p. 332.

The general explanation of these phenomena, given at the time, is briefly as follows: "A person places his hands, or any other part of his body, in a position of effort. . . . What must happen? Evidently, . . . there must be a rhythmical series of motions taking place between the antagonistic groups of muscles, because the rhythms, "*i. e.* of the susurri," of these cannot be synchronous.

At first the will restrains any tendency to marked vibration in the part, but the restraining influence being gradually diminished or held in abeyance, "we find, as a result of the exhaustion of neuro-muscular protoplasm, that a disturbance must take place. This disturbance must necessarily be rhythmical. Hence we have a rhythmical motion of the part, as shown by increased tremor. The action continuing, the tremor is succeeded by to-and-fro movements. At first it affects only the parts under strain, but this disturbance, which might perhaps be considered a purely local phenomenon, speaks through the mobile channels of the neuro-muscular appatatus, and affects it as a whole. Thus we see that, beginning with tremor of the hand, we finally have the flexors and extensors of the forearm thrown into violent clonic contractions. Next the muscles of the arm and shoulder are involved. At last, such a violent explosion takes place that the neck, the back, the legs, the diaphragm, the heart even, is affected."

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[1] "On the Artifical Induction of Convulsive Seizures," by F. X. Dercum, M.D., and A. J. Parker, M.D., JOURNAL OF NERVOUS AND MENTAL DISEASE, vol. xi., No. 4, October, 1884.

Now, that tremor should follow upon placing opposed groups of muscles in a position of strain, is perhaps nothing more than what we could expect from *a priori* consideration, and is indeed a fact in accord with common experience, but that *distant parts* not primarily involved in the experiment should become affected, is indeed remarkable. Evidently a general cause, one that acts upon the *entire nervous system*, comes into play. In the first place, the power of the brain to inhibit or overbalance the spinal cord, is through its expenditure in concentration of thought gradually lessened, until not only the muscles under strain are beyond the influence of the will, but also the entire muscular apparatus. Now, as we shall presently see, the states of tonus of the various muscles are closely correlated. A change of tonus in any one muscle affects the tonus of all the rest, and we can readily understand how such marked changes of tonus, as tremor, clonic movement, or tetanic contraction, are transmitted to different parts.

That the states of tonus of all the muscles are closely correlated, is a legitimate inference from the remarkable observations of Drs. S. Weir Mitchell and Morris J. Lewis[1] on the reinforcement of the knee-jerk by coincident muscular movement in distant parts, and also on its reinforcement by coincident sensory impressions. These studies have already become so widely known that it is perhaps unnecessary to give an account of them, however brief, here. Suffice it to say, that movements of the limbs, or even such slight movements as winking or swallowing, when coincident with the blow upon the tensor, produce increase of the knee-jerk. This increase is also present when a marked and coincident sensory impression is made, such as twitching a hair, pinching or pricking the skin. We have reason, then, to believe that whenever any one muscle has its tonus increased by a volitional effort, there is an overflow to the other muscles likewise, and also that the inflow of molecular movement caused by a sensory impression, is followed by an outflow, not through any one channel, but through many, probably through all. To quote the language of Drs. Mitchell and Lewis: "Under this view we conceive of the nervous force as not confined entirely to the direct paths between the centres and the muscle to be moved, but as overflowing so as to pass through numerous ganglia, adding a certain small increment to their effect when in a state of such activity as the spinal toning centres must be at all times." Certainly, it must be in some such way as this, that in our artificially induced convulsions, tremor and clonus are communicated from one group of muscles to another.

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[1] "Physiological Studies of the Knee-Jerk, and of the Reactions of Muscles under Mechanical and Other Excitants." By S. Weir Mitchell, M.D., and Morris J. Lewis, M.D. *Medical News*, vol. xlviii., p. 169 and 198. Jendrassik also observed increase of the knee-jerk by coincident clinching of the hands.

The facts brought to light by our experiments on artificial convulsions and the discoveries of Drs. Mitchell and Lewis can be explained on no other supposition than that the nervous system acts as a unit. The close and varied relation between distant parts demonstrated in so forcible a manner, admits of but one interpretation,—one, too, that is pregnant with thought. Inasmuch as every voluntary movement presupposes a corresponding mental action, the general mental state must be in more or less intimate relation with the general muscular tonus, and special mental states must stand in intimate relation with the tonus of special groups of muscles. A moment's reflection will convince us that this is the case. We habitually judge of a man's mental state by his facial expression, and this we know to be dependent upon the tonus of the facial muscles. We unconsciously judge of his personal traits, character, and disposition by his carriage and gait, which in turn we know to be dependent upon the tonus of the muscles of the trunk and limbs. Thus the varying states of the muscular tonus, though there are other factors, constitute a means by which we habitually acquire a knowledge of the inner nature of our fellows.

Again, facts physiological and pathological, show that the nervous system is related intimately to almost all, if not all, the other tissues of the body. We know it to be the case with the glands, the bones, the skin, and the appendages of the skin. We know that certain nervous affections are accompanied by disease of the bones, that the activity of certain glands is absolutely dependent upon their innervation, and varies markedly with mental states, that the skin sloughs in certain nervous lesions, etc., etc.

Standing in intimate relation to the nervous system, the activity of these tissues, as well as their nutrition and growth, are probably subject to conditions similar to those which govern the muscles. Doubtless, too, the activities of all the structures of the body are more or less closely inter-related. We are all familiar with the harmony of action existing among various viscera, with the atonic digestive troubles associated with depressive mental states, and with such facts as the arrest of digestion by violent physical exertion. Furthermore, the activities of the glands may at times be in even *intimate* relation with the muscular tonus, as can be inferred from the occasional behavior of the lachrymal glands and kidneys during the artificially induced convulsions.[1]

In this brief essay important facts have been merely mentioned and important principles merely touched upon, yet in summing up we may safely say that considerations of embryology and comparative anatomy, and various facts derived from other sources, point infallibly to the conclusion that the nervous system, though inextricably complex and composed of an almost infinite number of parts, *acts as a whole;* that it constitutes an engine the various parts of which are so closely inter-related, so mutually interdependent, that no one part can move unless every other part, no matter how slightly or how profoundly, moves also.

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[1] *Loc. cit.* The strange and mysterious facts of the correlation of nutrition collected by Darwin, may also find here a key-note of explanation.